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SIMULATION OF THE ELECTRIC DRIVES FOR THE 6-DOF MOVEMENT SYSTEM

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ABSTRACT

Nowadays the multi-degree-of-freedom movement systems constructed on the basis of spatial parallel mechanisms are widespread in the field of robotics and machine building [1]. The development of such multi-degree-of-freedom movement systems starts with the simulation and prototyping of kinematic, dynamic and control parts, as well as the electric drives then. The spatial movement characteristics, realized by such systems, directly depend on the electric drives performance. Therefore the problem of proper electric drives selection and simulation is among the issues that are usually dealt with while prototyping movement systems. The paper describes a rapid approach to simulation of the electric drives for the 6-DOF movement system constructed on the basis of spatial parallel mechanism.

1. 6-DOF MOVEMENT SYSTEM

The 6-DOF (six-degree-of-freedom) movement system consists of 6-DOF spatial parallel mechanism, six electric drives and control board. Visual image of the movement system considered is presented on Figure 1.

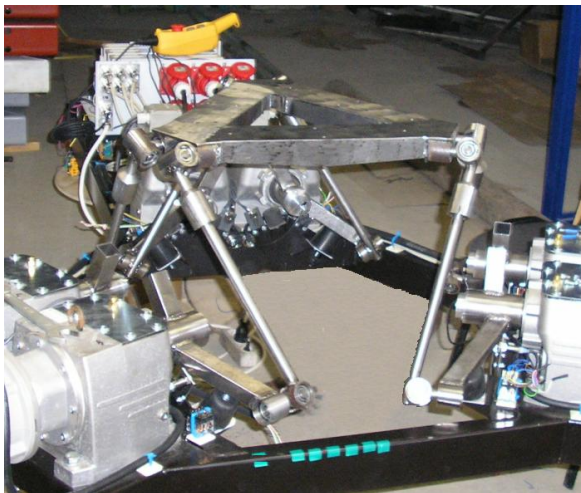


Figure 1 6-DOF movement system

The 6-DOF spatial parallel mechanism is composed of six independent legs connecting the mobile platform with the base. Each of these legs is a serial kinematic chain that is controlled by one electric drive which actuates one of the joints. Kinematic structure of the 6-DOF spatial parallel mechanism is capable of

realizing 3D movements of the mobile platform. The output position and orientation of the mobile platform directly correspond to the input actuation from electric motors driving shafts.

There are six identical, but controlled independently, electric drives in the 6-DOF movement system. Each electric drive consists in general of three basic parts: a three-phase asynchronous motor, a power control circuit, a regulator.

The movement characteristics such as precision and dynamic performance, realized by the mobile platform, mostly depend on the electric motors and power control circuits used in the electric drives. Therefore it's of an extreme importance to have a computer model of the electric drive to carry out a simulation at a stage of prototyping. The simulation having been carried out grants a possibility to select the electric drives with proper parameters and characteristics.

2. ELECTRIC MOTOR MODEL

The electric drive simulation starts with a mathematical model development for the electric motor being used.

A three-phase asynchronous machine model is implemented in MATLAB/Simulink modeling environment on the basis of the d-q model of induction machine in the reference frame rotating at specified speed and the second-order model representing motor's shaft rotation [2]:

$$\begin{cases} V_{qs} = R_s i_{qs} + \frac{d}{dt} \psi_{qs} + \omega \psi_{ds}; \\ V_{ds} = R_s i_{ds} + \frac{d}{dt} \psi_{ds} - \omega \psi_{qs}; \\ V_{qr} = R_r i_{qr} + \frac{d}{dt} \psi_{qr} + (\omega - \omega_r) \psi_{dr}; \\ V_{dr} = R_r i_{dr} + \frac{d}{dt} \psi_{dr} - (\omega - \omega_r) \psi_{qr}; \\ T_e = p(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}). \end{cases} \quad (1)$$

$$\begin{cases} \frac{d}{dt} \omega_m = \frac{1}{2H} (T_e - F \omega_m - T_m); \\ \frac{d}{dt} \theta_m = \omega_m. \end{cases} \quad (2)$$

In the equations sets (1) and (2): R_s, R_r – stator and rotor resistance respectively; V_{qs}, i_{qs} – q axis stator voltage and current; V_{qr}, i_{qr} – q axis rotor voltage and current; V_{ds}, i_{ds} – d axis stator voltage and current; V_{dr}, i_{dr} – d axis rotor voltage and current; ψ_{qs}, ψ_{ds} – stator q and d axis fluxes; ψ_{qr}, ψ_{dr} – rotor q and d axis fluxes; ω_m – angular velocity of the rotor; θ_m – rotor angular position; p – number of pole pairs; ω_r – electrical angular velocity; T_e – electromagnetic torque; T_m – shaft mechanical torque; H – combined rotor and load inertia constant; F – combined rotor and load viscous friction coefficient. The inputs to the three-phase asynchronous machine model are the regulated mechanical torque at the motor's shaft and voltage signals from power inverters. The outputs are stator and rotor currents and voltages, motor's shaft velocity and angular position.

3. ELECTRIC DRIVES SIMULATION MODEL

The 6-DOF movement system's electric drive simulation model with a structure chart presented on figure 2 has been implemented in MATLAB/Simulink modeling environment.

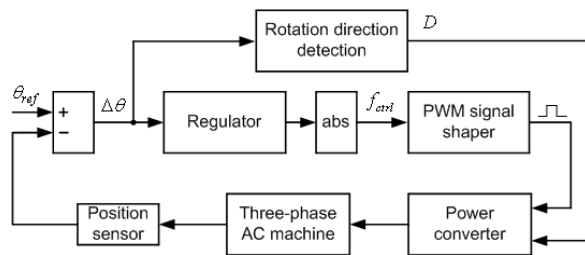


Figure 2 Electric drive simulation model

Signal θ_{ref} on figure 2 – is a reference signal setting the required motor's shaft angular position. The regulator realizes PID control law in the simulation model (figure 3).

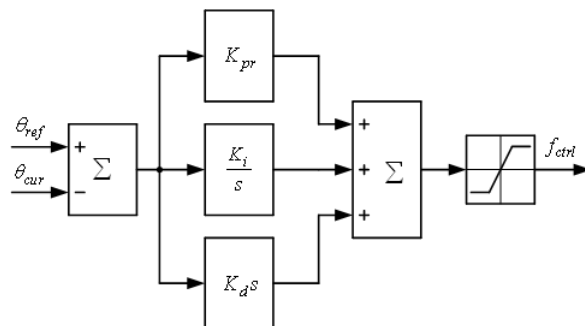


Figure 3 Simulation model regulator

It carries out the control of frequency f_{ctrl} so as to provide motor's shaft movement from θ_{cur} to θ_{ref} angular position in a specified time span.

The electric motor's rotor is short-circuited, and the stator is fed by a PWM signal shaper, built with Simulink blocks and interfaced to the three-phase AC machine block through the power converter scheme. The PWM signal shaper structure chart used in the model with implementation in MATLAB/Simulink environment is presented on figure 4.

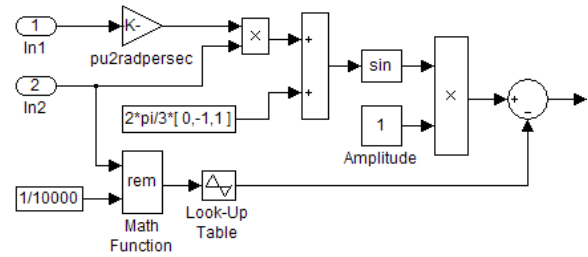


Figure 3 PWM signal shaper

It converts the f_{ctrl} frequency to the appropriate PWM signal using the triangular carrier wave's frequency which is set at 10000 Hz.

The power converter is realized on the basis of electrical sources, switches and relays blocks.

The developed electric drive simulation model, implemented in MATLAB/Simulink, enables PID regulator tuning according to motor output characteristics (rotor speed, rotor rotation angle, electromagnetic torque, rotor and stator currents).

4. CONCLUSION

The simulation of the electric drives for the 6-DOF movement system has been outlined in the paper. The model enables simulation with different three-phase AC electric motors parameters. In conjunction with kinematic, dynamic and control models electric drives simulation model can be used for rapid prototyping of the 6-DOF movement system.

5. REFERENCES

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